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When App Stores Listen to the Crowd to Fight Bugs in the Wild

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Abstract—App stores are digital distribution platforms that put available apps that run on mobile devices. Current stores are software repositories that deliver apps upon user requests. However, when an app has a bug, the store continues delivering defective apps until the developer uploads a fixed version, thus impacting on the reputation of both store and app developer. In this paper, we envision a new generation of app stores that: (a) reduce human intervention to maintain mobile apps; and (b) enhance store services with smart and autonomous functionalities to automatically increase the quality of the delivered apps. We sketch a prototype of our envisioned app store and we discuss the functionalities that current stores can enhance by incorporating automatic software repair techniques.

I. INTRODUCTION

Increasingly, mobile devices are infiltrating most of our daily activities, and consumers are using more and more mobile applications (apps for short). They download apps from dedicated app stores (Google Play, Apple Store, Amazon Appstore, etc.), which are in constant growth. In 2013, Google Play Store reached over 50 billion app downloads ¹.

Previous studies have shown that these stores deliver a significant portion of buggy apps to mobile devices. For instance, we have identified 10,658 buggy-suspicious apps in a dataset of 46,644 apps collected from Google Play Store [5]. Currently, the repair activity of defective apps is manually performed by app developers. After fixing the identified bugs, developers upload the new version (with the fixes) to the app store. Unfortunately, the time between the release of the defective app and the fixed version can be long. As a consequence, in the meantime, consumers continue to download defective apps and to experience undesired behaviors. This paper proposes the idea of an app store that orchestrates hot patches in production to overcome this issue.

To fight bugs in the wild, we devise the following approach. Defective apps are detected by constant analysis of user feedback in the form of reviews and ratings. While previous research studied user feedback in app stores [8], [6], [9], [4], none of them proposed mechanisms to exploit feedback by app stores themselves, autonomously. Next, the app store generates tentative hot patches for fixing app crashes. Finally, it monitors the performance of the fixed apps in the wild to learn about the correctness of the repairing and patch delivery process. The proposed strategy allows the store to detect, repair and validate defective apps without developers' intervention.

This orchestration is a feedback loop, since the app store itself takes decisions based on the outcome of the previous ones. If a patch generation technique fails (e.g., the fixed app still crashes), the store learns from these failures; If a delivery strategy distributes patches to the wrong set of devices (e.g., not all the devices suffer from the same bug), the store detects it. The app store continuously monitors both the fixed apps' execution and the user's feedbacks as an oracle of the autonomous improvement process. To sum up, we envision app stores that go beyond the role of app repositories and become intelligent agents. In this vision, app stores autonomously take decisions to improve the quality of experience of their customers.

To sum up, our contributions are:

- A blueprint of a smart app store capable of automatically detecting, generating, and validating patches using crowd-sourced information;
- A prototype implementation of such a smart app store;
- A preliminary evaluation over one real defective application from the Google Play Store.

The reminder of the paper is organized as follows. Section II describes the key components that form the infrastructure. Section III presents a prototype to demonstrate the feasibility of our proposal. Section IV reviews the related work. Section V concludes the paper.

II. VISION OF A SMART APP STORE

In our vision, app stores will incorporate two types of mechanisms in order to fight bugs in the wild: 1) *proactive mechanisms*, the store anticipates the emergence of bugs wild upon submission of new apps using static app checkers [5]; and 2) *reactive mechanisms*, the store acts when users experience bugs after installing apps. While this paper focuses on the latter, both mechanisms are complementary and can be activated simultaneously.

The smart app store we envision is capable of: a) retrieving and consolidating information from app's users and from devices running those apps, b) identifying apps that work unexpectedly in the wild (i.e., contain bugs), c) generating patches automatically for the identified defective apps, d) delivering fixed apps contextually, and e) validating the generated patches automatically from information received from devices.

Figure 1 depicts an overview of the smart app store we propose. This infrastructure builds on the principles of autonomic computing [7] and presents an architecture based on a feedback loop model, which combines five components:

¹<https://www.abiresearch.com/press/android-will-account-for-58-of-smartphone-app-down>

the patches are in an evaluation process to assess their validity. The component delivers a validated variant, if present. Otherwise, it delivers an under-validation variant. In the absence of variants, the store delivers the original app.

To select the variant for delivery, the component analyzes and compares the available information regarding all the variants. The store implements different app selection heuristics. For example, one heuristic delivers the variant that provides better performance (*i.e.*, less crashes) observed in similar devices (*i.e.*, same OS version). Another heuristic is based on user feedback: it selects the variant with the highest user ranking.

After delivery, the store registers the variant that delivers to each user. The pairs *user-variant* allows the store to monitor the performance of the patched apps in the crowd for, later, deciding whether the applied patches are effective or not.

Using information from the crowd, the App monitor component validates the generated patches and removes those *under-validation* variants that continue exhibiting wrong behavior (not available for subsequent delivery). The component applies similar heuristics to those ones previously presented, for example, discarding variants whose rankings are worse than those from the original app.

The component passes a variant from *under-validation* to *validated* after, for instance, delivering and observing a correct behavior for a given number of users. In this case, the Patch validation component notifies all the users that run a different *variant* of the app that a new fixed version is released and is available for downloading.

III. PRELIMINARY RESULTS

We have implemented a prototype of the smart app store to demonstrate the feasibility of our proposal. To illustrate this approach, we use an Android app that contains bugs: the *PocketTool*² app downloaded from Google Play Store. The subject app enables the personalization (*i.e.*, download/install textures and skins) of the popular game *Minecraft*³. Once the app is launched, if the user clicks on the button “Level Editor” then the app crashes. Figure 2 (a) shows the screenshot of the crash thrown by the *PocketTool* app.

A. Implementation of the Smart App Store Components

Monitoring and Analyzing User Feedbacks. The healing process starts when the store observes user reviews complaining about bugs and crashes. To identify user reviews that treat themes related to bugs, we extract topics discussed in the corpus of reviews using *Topic Modelling*. Our system classifies as *error-related* reviews the ones which are mainly composed by topics related to bugs and failures. Then, it flags as *buggy-suspicious* the apps whose ratio of error-related reviews reaches a predefined threshold (cf. [5] for implementation details). Our system enables the identification of 10,658 buggy-suspicious apps in our dataset (composed of 46,644 apps) collected from Google Play Store. This system enabled the identification of the subject app used in this experiment.

Monitoring and Analyzing Execution Traces. This step is triggered when an app is flagged as buggy-suspicious. Then, the App monitor component uses the Android Logging system⁴ (*logcat*) to monitor exceptions raised by the buggy-suspicious app. In Android, the system collects debug information from apps and from the system in logs, which can be viewed and filtered by the *logcat*. The logs include stack traces when an app throws an error. We have implemented a listener that monitors the *logcat* and subscribes to error logs. The listener notifies to the store whenever an exception is detected in an app. Figure 2 (b) shows the exception trace (extracted from the *logcat*), which is thrown by the *PocketTool* app. We observe that the exception is related with a *NullPointerException*. The exception trace reveals some methods implemented in the *PocketTool* app (lines 5–6 in bold), and other methods defined internally by Android libraries (lines 1–3).

Planning Alternative App Releases. First, the Patch generation component processes the exception trace and extracts the n frames that refer to the suspicious app. In our example, the 2 frames that start with the package name of the app (`com.snowbound.pockettool.free`). From each suspicious frame, it extracts the name of the suspicious method and the class that implements it. In our example there are 2 suspicious methods (cf. Fig. 2, lines 5 and 6): `getWorldList` and `onCreate`, defined in the class `LevelSelector`.

Next, the component creates n different patches, where n is the number of suspicious methods. In our implementation, the patch wraps the code defined inside the suspicious methods with a `try/catch` block to capture the runtime exceptions that are not handled by the methods. We create 2 patched versions of the defective app, where each patch wraps a different suspicious method. To inject the patches, we have implemented a Java program⁵, which instruments the bytecode of Android apps using *Dexpler* [2].

Executing the Deployment of Apps. Finally, the different patched app versions are deployed in different user devices. First, the buggy app is uninstalled, and then the new patched version is installed. To communicate with devices, our implementation relies on the *Android Debug Bridge* (*adb*)⁶. *adb* is a command line tool (included in the Android SDK), which acts as a middleman between a host and an Android device. We use *adb* to remotely install/uninstall apps and to read the *logcat*.

To validate the candidate patches, the App monitor component observes if the fixed app throws the same exception as the original app when running on devices. If the exception still arises, then the patch is considered as invalid and the store discards it. On the contrary, if the exception disappears after patching, then the patch is considered as valid and the store will deliver it in subsequent app requests.

B. Experimental Results

We observe that the patch applied in the `onCreate` method (Patch2) avoids the crash, whereas the patch applied

²<https://play.google.com/store/apps/details?id=com.snowbound.pockettool.free>

³<https://play.google.com/store/apps/details?id=com.mojang.minecraftpe>

⁴<http://developer.android.com/tools/help/logcat.html>

⁵Our instrumentation program is available for download: <https://www.dropbox.com/sh/u3ffy1lw85opww8/AACBLu2zcTCUNgXAFh7dpDbma>

⁶<http://developer.android.com/tools/help/adb.html>

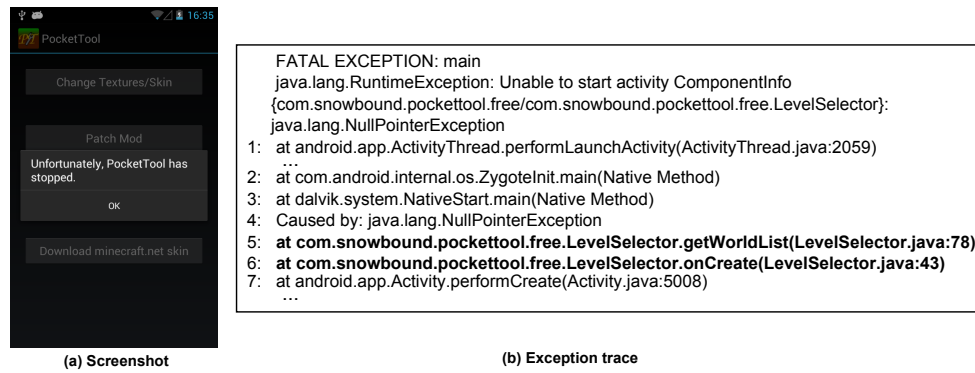


Fig. 2. (a) Screenshot of the subject app crash. (b) Exception trace raised by the subject app (in bold the methods defined in the app).

in the `getWorldList` method (Patch1) continues throwing the exception. Therefore, the store learns that Patch1 is not effective and automatically discards it.

Our proposed implementation takes as input *.apk* files and works remotely with devices without requiring USB connection. We run the experiments in a rooted device Google Nexus S with Android 4.1.2. We generated 2 patched versions of the *PocketTool* app (original size 395 Kb). Each patch rewrites the bytecode of the subject app to inject a `try/catch` block that wraps the code defined in the methods `getWorldList` (Patch1) and `onCreate` (Patch2), respectively. The size of the two patched apps is 439 Kb, and the total time to rewrite the bytecode and redeploy the apps in the device is 51 seconds, which we consider is an acceptable overhead.

IV. RELATED WORK

Recent approaches have investigated different sources of information available on app stores: AR-MINER [8], WISCOM [4], Harman et al. [6], Pagano and Maalej [9]. The aforementioned approaches provide significant analysis about the user feedbacks available on app stores. Nevertheless, none of them provide mechanisms to exploit the user feedback by the stores themselves.

Azim et al. [1] present a self-healing approach to automatically detect failures and patch Android apps to avoid crashes. As in our approach their patching strategy rewrites the bytecode of apps to insert `try/catch` blocks to wrap methods that throw unhandled exceptions. Nevertheless, our approach generates different patches for a buggy app and uses user feedbacks to evaluate the feasibility of the patches. Franz et al. [3] define an app store which generates different versions of an app, functionally identical, upon reception of download requests. The goal of their work is to reduce the vulnerability of apps. In our approach, we generate and distribute app versions with differences in functionality. These differences consist of candidate patches to validate. In contrast to previous work, our goal is to engineer smart app stores that exploit user feedbacks and incorporate repairing techniques to avoid the distribution of defective apps among users. To the best of our knowledge, we propose the first autonomic computing approach to monitor and repair mobile app crashes in the wild that continuously improves its autonomous strategies based on crowd feedback.

V. CONCLUSION

In this paper, we have presented the vision of app stores that exploit user feedbacks and take autonomous decisions to improve themselves. A smart app store is able to automatically detect defective apps and provide different patches to avoid bugs. After deploying patches, the store learns which the effective patches are and improves its repairing strategy. We have presented a prototype implementation and its usage on a real defective app from Google Play Store.

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